MP4-Karver: CARVING OF CORRUPTED MP4 VIDEOS USING ASMD REPAIRING TECHNIQUE

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Corrupted MP4 Carving using MP4-karver

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A thesis submitted in
fulfillment of the requirement for the award of the
Degree of Master of Information Technology

Faculty of Computer Science and Information Technology
Universiti Tun Hussein Onn Malaysia

July, 2016

DEDICATION

All praise and thanks are due to Almighty Allah, Most Gracious; Most Merciful, for the immense mercy which have resulted in accomplishing this research.Thank you Allah giving me health.

Greatly indebted to my elder brother,
Abdiqadir Elmi Abdi;
My parents,
Elmi Abdi Rage,Dhuh Jama Abdirahman;
My siblings
Special thanks are due to my colleagues and postgraduate members, friends and among many others.

ACKNOWLEDGEMENT

I would like to acknowledge and appreciate my supervisor Dr. Kamaruddin Malik bin Mohamad, for his support long towards my research through his remarkable guidance, support, determination, encouragement, understanding and patience along this journey are truly appreciated.I would also take this opportunity to thank Universiti Tun Hussein Onn Malaysia (UTHM) for supporting this research under the Graduate Research Grants (GIPS) vote no U307.

I am greatly grateful to Faculty of Computer Science and Information Technology (FSKTM) and Center for Graduate Studies (CGS) of UTHMfor providing me the facilities and opportunity to pursue my graduate studies and complete this study comfortably.I admit, with enormous gratitude and inspiration; encouragement, valuable time and guidance showered by my postgraduate members and friends.

ABSTRACT

The usage of digital video is rapidly increasing recently. The analog CCTV systems are replaced by digital systems. Moreover, digital cameras and smartphones are increasingly popular and becoming affordable. The criminals use these digital devices; particularly smartphones to record crimes such as child pornography and other violent activities. Many at times, these videos are altered or deleted by the criminals in order to avoid persecution by the law enforcement. In digital forensic, carvings of deleted, damaged video files have an important role in searching for evidence. Therefore, many existing tools and techniques such as Scalpel's, PhotoRec, Bi-Fragment Gap Carving (BGC), Smart Carving and Frame Based Carving attempt to carve the videos files, but some of the carved videos files are usually corrupted or damaged and not playable. However, there is still room for improvement in repair corrupted MP4 videos to make it playable. In this research, MP4-Karver tool is proposed to carve and repair the corrupted MP4 videos. MP4-Karver is developed by using visual studio platform in C# programming language. The proposed MP4-Karver tool focuses on carving, repair corrupted MP4 videos and getting a higher successfulrate of playable MP4 video file format. The experimental result shows that the proposed MP4-Karver tool increases the restoration carving and repairing of MP4 corrupted videos with average of 97% improvement as compared to PhotoRec and Scalpel. The MP4-Karver tool is a good alternative for MP4 videos restoration and repairing damaged videos as compared to other tools and techniques.

ABSTRAK

Penggunaan video digital semakin meningkat hari demi hari secara pesatnya sejak kebelakangan ini. Kebanyakan sistem analog CCTV telah digantikan oleh sistem digital. Tambahan pula, kamera digital dan telefon pintar semakin popular dan harganya telah menjadi mampu milik. Penjenayah-penjenayah juga telah menggunakan peranti-peranti digital ini terutamanya telefon pintar dalam merekod jenayah mereka seperti pornografi kanak-kanak dan aktiviti-aktiviti keganasan yang lain. Walaupun begitu, kebanyakan video-video ini telah diubah atau dipadam oleh penjenayah demi mengelakkan diri dari hukuman pihak berkuasa. Di dalam forensik digital, mengukir fail video yang dipadam dan rosak memainkan peranan yang penting dalam penyiasatan bukti-bukti. Oleh itu, banyak pendekatan sedia ada seperti Scalpel , Bi-Fragment Gap Carving, Smart Carving dan Frame Based Carving telah digunakan dalam usaha untuk mengukir video-video dengan kaedah-kaedah yang berbeza, namun video-video yang telah diukir kebiasaannya tidak dapat dimainkan. Walaupun begitu, alat-alat dan teknik-teknik pegukir fail ini tidak berupaya untuk membaiki video MP4 yang telah rosak dan menjadikan video tersebut supaya boleh dimainkan semula. Di dalam kajian ini, alat MP4-Karver telah dicadangkan untuk mengukir dan membaiki video yang telah rosak. Alat ini dibangunkan di dalam bahasa pengatucaraan C#. MP4-Karver yang dicadangkan,mangutamakan fungsi ukiran dan membaik pulih video yang telah rosak kepada video yang boleh dimainkan semula. Keputusan eksperimen menunjukkan MP-4 Karver ini berupaya meningkatkan tahap nisbah pemulihan MP4 dan membaik pulih video yang rosakdengan kadar 97% lebih baik berbanding dengan alat-alat yang lain seperti PhotoRec dan Scalpel. Kesimpulannya, alat MP4-Karver ini mampu menjadi alat alternatif dalam membaik pulih video MP4 yang telah rosak berbanding alat-alat yang lain.

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LIST OF SYMBOLS AND ABBREVIATIONS

PDF	-	Portable Document Format
AVI	-	Audio Video Interleaved
WAV	-	Waveform Audio File Format
MP3	-	MPEG Audio Layer 3
MOV	-	QuickTime Movie (file extension)
3D	-	Three-Dimensional film
AVC	-	Advanced Video Coding
FTYP	-	File type box
MOOV	-	Movie box
MDAT	-	Media Data Box
GIF	-	Graphics Interchange Format
JPG	-	Joint Photographic Experts Group
PNG	-	Portable Network Graphics
SWF	-	Small Web Format
FLV	-	Flash Video
DFRWS	-	Digital Forensics Research Workshop
CCTV	-	Closed-Circuit Television
MP4	-	MPEG-4
FAT16	-	File Allocation Table 16
NTFS	-	New Technology File System
P2P	-	Peer-to-peer
STSZ box	-	Sample Size Box
NFI	-	Nederlands Forensisch Instituut
ASF	-	Advanced Systems Format
3GP	-	Third Generation Partnership

MMC	-	Microsoft Management Console
USB	-	Universal Serial Bus
eDiscovery	-	Electronic discovery
CD-ROMs	-	Compact disc used as a read-only optical memory
APIs	-	Application program interface
MD5	-	Message Digest 5 Algorithm
SHA1	-	Secure Hash Algorithm 1
IRS-CI	-	Internal Revenue Service Criminal Investigation
PC	-	Personal Computer
AVC	-	Advanced Video Coding
2D	-	2-Dimensional
DVD	-	Digital Video Disc
ASMD	-	Automatic Standard MP4 Duplicator

LIST OF APPENDICES

LIST OF PUBLICATION

Journal:

(i) Ahmed Nur Elmi Abdi, Kamaruddin Malik Mohamad, Yusoof Mohammed Hasheem, Rashid Naseem, Jamaluddin and Muhammad Aamir, "Corrupted MP4 Carving Using MP4-Karver" International Journal of Advanced Computer Science and Applications(IJACSA), 7(3), 2016.

CHAPTER 1

INTRODUCTION

1.1 An Overview

The application of smart devices, such as smartphones and CCTV recording videos has increased tremendously, especially in the last decade [1]. One of the remarkable technological breakthroughs of the 21st century is the invention of devices, such as the smartphones, digital cameras, CCTVs and security cameras, which are used to capture images and record videos of events. The demand for these devices from individuals and business corporations keep increasing which results from more productions and in turn, makes their prices much lower [2].

Besides, these devices are also used to record illegitimate and criminal activities, such as murder, robbery, and rape. The information retrieved from these devices can be used to identify criminals involved in a particular crime and being brought to justice. In criminal investigations, recorded video data on storage media often provides important evidence for a case. To ease the effort to search for recorded video data about crime, video data restoration and video file carving has been actively studied [3]. Carving of corrupted or damaged video files has an important role in digital forensics for finding every bit of video data and making it viewable which can be crucial to the investigation.

Conventional file restoration techniques find meta-information of the deleted files to search for physical locations containing actual file contents [4]. However, the file cannot be restored if the file links are lost.

Since a video file typically has a large volume, it is very likely to be fragmented or corrupted although the meta-information remains in the file header. The existing techniques were signature based file restoration technique such as Bi-fragment gap carving (BGC) technique, Smart carving technique, and Frame-based recovery. These techniques introduced the method of providing a signature to the file system, i.e. providing header and footer to the file system. However, this technique is not efficient when a target video file was severely fragmented, corrupted or even has a portion of video overwritten by other video contents. The ability of existing techniques to retrieve the videos is less than 50% [5].

In this study, an improved MP4 carving tool has been proposed, in which corrupted and non-corrupted carves MP4 files from mobile phones or CCTVs could be made playable again. The proposed tool has been developed using the C# programming language.

1.2 Problem Statement

The use of digital video has been rapidly increasing. Analogue CCTV systems have been replaced by their digital counterparts. According to Pew Research, criminals use digital devices, such as digital cameras and smart phones to record crimes, such as child pornography and other violent activity. Many times, these videos were altered or deleted by the criminals in order to avoid prosecution by the law. In digital forensics, it is important to retrieve and carve damaged or deleted videos. Finding every bit of video data and making it reviewable can be crucial to the investigation. Many existing approaches have attempted to carve a video file using the header of the video. In some cases, a target video file is severely fragmented, corrupted or even has a portion of video overwritten by other video contents. However, existing video file carving approaches fail to carve non-playable or incomplete MP4 videos. For instance, PhotoRec and Scalpel tools are not able to carve non-viewable, incomplete files from corrupted, fragmented video files. This research proposes an automatic repairing technique for carving corrupted MP4 video files that are complete and playable.

1.3 Aim and objectives of study

The aim of this study is to propose an improved toolforcarving and repairing MP4 video files. To help digital forensic investigators to search evidence from carving corrupted MP4 videos and make it playable.

The objectives of this research are:

(i) To propose automatic repairing technique for carving corruptedMP4 video files.

(ii) To developand implementing the proposed tool(i);

(iii) To test the accuracy of successful number of playableMP4 videos carved using DFRWS 2007 and Level_3 datasets and compare it with PhotoRec and Scalpel carver tools.

1.4 Scope of study

This research focuses on carving to acquire higher successful carving rate on playable MP4 video files. The proposed tool only evaluates the accuracy of the carving number of playable MP4 videos. This research particularly deals with carving corrupted, damaged, incomplete MP4 videos into re-playable videos, even for MP4 video that was produced from CCTV or any other devices built with cameras.

1.5 Outline of the thesis

The rest of the chapters in this thesis are organized as follows: Chapter 2 gives an introduction of file carving, the existing file carving tools and techniques, comparison of existing tools, magic numbers, MP4 overviews and performance measurement. Chapter 3 discusses research framework. Chapter 4 discusses algorithm development, MP4-Karver components and software/hardware requirements. Chapter 5 elaborates the experiments and results obtained from MP4-Karver, PhotoRec, and Scalpel. Finally, Chapter 6 concludes the research and gives suggestions for future work.

CHAPTER 2

LITERATUREREVIEW

2.1 Introduction

Carving of damaged or corrupted video files obtained from a crime scene may provide key evidence to resolve the case. Conventional techniques for video file restoration makes use of meta-information the file system to retrieve a video file stored in a storage medium, such as a hard drive or a memory card [6]. The file system's meta-information contains some system data, such as the address and the link to a video file that can be used for file restoration. Carrier proposed a file restoration tool based on a file system, which was implemented in software toolkit[7]. Sleuth Kit is based on information from the file and directory structure of a storage file system. Video file restoration may not be possible with such technique when the file system's meta-information is not available [8].

Thus, attempts have been made to restore the video data from video contents, rather than the meta-information of a file system. This research also introduces a technique to restore damaged or corrupted video files irrespective of a file system. A signature-based video restoration technique proposed to address this problem[9]. The method creates a database of the file header (i.e. the beginning mark of a file) and footer (i.e. the end mark of a file) and defines a set of rules for a specific file type. This signature-based file recovery technique does not require file system information, which can be applied to a video file without meta-information because of file system change and reformatting of a storage medium. The signature-based file recovery techniques identify fragments from byte sequence (or magic bytes) containing file header or footer.

The scalpel does not rely on a file system to restore a video file [10]. This technique requires an indexing step to find the file header and footer from whole disk as well as a restoration step to recover the indexed header and footer. It does not use file system's metadata to restore data between header and footer to a file.

However, this method has limitations when the files are un-fragmented. It does not recover partially overwritten video files. Garfinkel utilized additional information stored in a file to extend the idea to signature-based restoration techniques. For some files, the header may contain the information of file size or length. When the file footer does not exist, they can use this information to extract a file [11].A video file can be restored using Bi-fragment gap carving (BGC) [12]. This method finds a combination of the region containing the header and the footer to test if a video sample is valid. It computes the difference between two data regions and checks if the difference passes a predefined validation procedure. This procedure repeats until the gap passes the validation test. However, this method can only be applied to a video file with two fragments and it does have limitations when the gap between the two file fragments is large.

Smart carving technique was proposed to restore a file without being restricted by the number of fragments [13]. This technique identifies occurrence of fragmentation combines permutations of fragment components and searches for the order of fragments. The technique consists of three steps, namely preprocessing, collation, and reassembly. The preprocessing step collects called block part, which was not allocated to a file using the file system information to reduce the size of data to be analyzed. The collation step categorizes collected blocks in the preprocessing step according to a file format. Lastly, the reassembly step determines fragmented parts and merges them into a file. This step increases restoration rate of the multimedia file by assigning a weight to each fragment using decoded frame difference. However, the method also uses a file-based approach and it has difficulty in restoring a video file when a part of video file was overwritten [14].

2.2 File carving

“File carving,” or constantly simply being called “carving,” is the process of extracting a collection of data from a larger dataset. Moreover, the data carving technique is frequently operated during a digital investigation when an unallocated file system space is analyzed to extract files. The files are carved from the unallocated space using file type-specific header and footer parameters. File system structures are not used during the process. The file carving is a powerful technique for recovering files and fragments of files when the directory entries are corrupted or missing. The data are searched block by block for residual data matching the file type-specific header and footer parameters. Through that carving is also especially useful in investigating criminal cases where it may be able to recover evidence. In certain cases related to child pornography, law enforcement agents are often able to recover additional images from a suspect’s hard disk using carving techniques [15]. Moreover, forensic experts use file carving to squeeze every bit of information out of this media. As long as data is not overwritten or wiped, deleted data on all storage devices could be restored using carving techniques, including multifunctional devices and even mobile phones. Depending on the conditions, it is even possible to restore data from formatted disks. With the exhaustive measures of drives since 2006, there is huge chance that the data is not overwritten. For instance, let’s say you have a two-terabyte drive, and you delete a document from that drive. The disk space reserved for that document will be marked “available,” but it could actually take a long time before this address space on the disk is overwritten. There were forensic cases where discovered files stored on the disk years ago. File carving deals with raw data on the media and doesn’t use the file system structure in its process. A file system, such as FAT16, FAT32, NTFS, EXT, is a structure for storing and organizing computer files and the data they contain. Though carving doesn’t care about which file system is used to store the files, it could be ideal helpful to understand how a specific file system works. File carving techniques could be header-based, file structure and block-based carving, as well as the role of file validation in the file carving process [16].

2.3 MP4 Video file carving

Video sharing over the internet has become highly popular in the last few years. In the past, when the internet was not fully developed in terms of speed and bandwidth, the users were required to download an entire multimedia file and then save it to local disk before being able to view it [17]. Today, with the availability of very fast and affordable internet connections in most countries, multimedia contents can now be streamed over the internet without needing to download all of them first when viewing. In addition, a significant amount of video contents is being distributed over Peer-to-Peer (P2P) file sharing techniques [18]. With the advent of powerful mobile computing devices (e.g. smart phones and tablet PCs) and high-speed mobile data networks (e.g. 3G, 4G), together with social media services, the amount of video distribution over the internet has been growing exponentially. In accordance with this, the amount of shared illegal videos has also increased.

As in most countries, not only the distribution, but even the possession of certain image and video data are illegal, e.g. material containing child pornography, findings of such data during forensic investigations can be very important for evidence. Therefore, the capability of recovering and analyzing video data is crucial for them. During digital forensic investigations, investigators often encounter a situation where they are required to recover deleted data from a seized storage device. Traditional data recovery techniques are based on file system information. Such techniques use file system metadata information to recover deleted or corrupted files. In the case when metadata information is not available or the file system itself is damaged, these techniques cannot be used to recover the deleted files. That is the reason, we use advanced forensic techniques, such as file carving that works completely independent of the underlying file system [19]. With the file carving technique, the deleted contents could be recovered as long as they were not over-written.

2.4 Existing videocarving tools and techniques

In this section, the existing file carving tools of Defraser, PhotoRe, EnCase , iLook , R-Studio and techniques of Smart Carving, Bi-fragmented Gap Carving, Frame based on Recovery are discussed.

2.4.1 Smart Carving

File carving is one of the methods that recover files by taking complete advantage of their building and also its contents without even looking for file system information at all. Aside from that, the main contribution of smart carving is quite possibly related to existing approaches which have been used to recover other media files. The research which is related to the multimedia file formats shows anentire overview of the current development that is done by file carving. Even more impressive, the last paper shows the results after implementing the methods. This technique focuses more on a content-based carving of multimedia files from various different types of storage media available to us today. These multimedia files can also be files which store both video and audio information just similar digital movies [20]. The codec is basically video data that are compressed and the program that shrinks the required amount of data is usually for the support of HTML5thus web browser can support the playback of the video files. Meanwhile, the plans of carving are quite significant for carving in the case of a disaster, e-discovery, and forensics [21].Moreover, file system's meta-data in general, are based on an existing technique for carving files either from corrupted storage media.

Smart Carving is also used for carving out fragmented files and results shows that it is an improved method. This technique contains three steps for carving fragmented files, namely collation, preprocessing, and reassembly. The first step deals with the file system structure that still exists and is valued, such as the areas of data blocks using file carving to find fragmented files that should be recovered.

In the second step, the classification file type is unallocated and unreferenced data blocks using file carving to find fragments that should be recovered. In the last step, to actually acquire to the original sequence, the reassembly may detect fragments and then it is assembled from there.

2.4.2 Bi-fragmented Gap Carving (BGC)

The Bi-fragmented Gap carving is another technique which is used to carve and restore damaged video files[22]. Moreover, the technique uses certain metadata which are found in the file header and it is used as a signature to recover the video files. For instance, metadata isthe length and size of the file. The technique is efficient such that even when the file footer is not available, the information found in the header is sufficient for the file recovery. By using the technique, the validity of a video file can be tested. Moreover,this can be done by finding a region where both the header and footer are available. Nevertheless, the difference between two regions is computed to determine if it passes the validation procedure. This test is continuously repeated until the gap passes the test. However, the technique uses a brute force approach to carve video file. This means that it searches for all possible existing clusters between an identified file header and footer until a valid video file is found. Though, it does have certain limitations. It is not applicable when a video has additional than two fragments or when the file structure is missing. In addition, it is not efficient when the fragmentation gap is actually wide. Mostessentially successful decoding and validation do not always imply that a file was reconstructed correctly.

2.4.3 PhotoRec

PhotoRec is an open-source digital forensic tool designed to restore lost or deleted files, such as document, audio, video, picture from the disk image. It retrieves deleted files using signature matching of the file and does not consider the storage media file system metadata. It performs the block level reading of media, each block is checked against the signature database. It can carve lost files from digital camera storage media of CompactFlash, Memory Stick, SmartMedia, Microdrive, MMC, USB flash drives, hard disks, and CD-ROMs. Moreover, it restores most common photo formats, audio files, document formats, such as Microsoft Office, PDF, HTML, and archive or compressed formats. However, it does not attempt to write to the damaged media from where carving is being performed [23].

2.4.4 EnCase

Encase is a very widely used digital forensic tool to conduct an investigation from beginning to the end. It has the capability to manage a large number of evidence during the investigation. However, it is equipped with a file carver module which does the carving using signature-based methods and it can also examine unallocated spaces. It is a digital forensic product by Guidance Software. The tool comes in several forms designed for forensic, cyber security, and eDiscovery. It contains tools for several areas of a digital forensic process: acquisition, analysis, and reporting. It also includes a scripting facility called EnScript with various application program interface (APIs) for interacting with evidence.

The EnCase contains functionality to create forensic images of suspected media. Images are stored in proprietary EnCase evidence file format; the compressible file format is prefixed with case data, information and consists of a bit-by-bit (i.e. exact) copy of the media interspaced with hashes (commonly MD5 or SHA1) for every 64KB of data. The file format also appends an MD5 hash of the entire drive as the footer onto the image file. EnCase is available for use on most major operating systems,but is primarily a Windows-based application [24].

2.4.5 iLook

ILook is a comprehensive digital forensic tool to analyze and acquire digital media files. Its investigator tool includes ILook v8 digital forensic tool and IXimager, which are both designed to follow forensic best practices. These two meet the digital forensic needs of Law Enforcement and Government. However, it is a powerful multi-threaded, Unicode compliant, fast and efficient forensic analytical tool designed to examine digital media from seizing computers or other digital media. It has robust processing capabilities, including advanced e-mail reconstruction and analysis, thorough and comprehensive indexing capabilities, a wealth of reporting features, and advanced unallocated space data salvaging capability.

Furthermore, it is an all-in-one computer forensics suite, originally created by Elliot Spencer and currently maintained by the US Department of Treasury, Internal Revenue Service- Criminal Investigation Division (IRS-CI) Electronic Crimes Program. Moreover, it was made available at no cost to law enforcement agencies and US government agencies at the discretion of the IRS-CI but is not available to the general public [25].

2.4.6 Scalpel

A scalpel, a popular open-source file recovery tool, performs file carving using Boyer-Moore string search algorithm to locate headers and footers in a disk image [30].Moreover, it carves files in two phases. In the first phase, it searches disk image to determine the location of headers and footers. This phase results in a database with entries.

This database contains the metadata (i.e. start location of a file, file length, file type, etc.) for the files to be carved. Meanwhile, the names of the files cannot be recovered (as these are typically stored only in the disk directory, which is presumed to be unavailable), synthetic names are assigned to the carved files in the generated metadata database. Though, the second phase uses the metadata database created in the first phase to carve files from the corrupted disk and write these carved files onto a new disk. Even with maximum file length limits on the size of files to be recovered, a very large amount of disk space may be needed to store the carved files. Thus,this method is limited to the cases when the files are non-fragmented and it does not recover partially overwritten video files.

2.5 ExistingMP4 video repairing techniques and tools

In this section, the related work of repairing techniques andtools are discussed. Moreover, the related finding in the field of repairing MP4 videos that has been done by other researchers is discussed in detail subsequently.

2.5.1 Corrupted MP4 video

In this section discusses comprising between playable MP4 video and corrupted MP4 video. The Figure 2.1 (a) shows the structure of a playable video file, while Figure 2.1 (b) presents structure of corrupted video file. Figure 2.1 (a) begins with file type box (ftyp) and Movie box (moov), followed by Mdat (Media Data Box). Normally, this 'mdat' would contain raw video data (H.264 NAL units). Figure 2.1 (b) contains the 'ftyp' and 'mdat' atoms only.

(a) (b)

Figure 2.1(a): Playable MP4 file structure and (b): Corrupted MP4 file structure

2.5.2Frame-Based Recovery of Corrupted Video Files Using Video Codec Specifications

This technique carves corrupted videos by taking advantage of their video codec. In this method, a video file is converted into video frames where every frame is an important part of the video file. Every video's still image is encoded using the codec's specifications. Each frame also contains a decoding start with data at the initial and end of a frame, which is used to decode a complete video frame. The restoration is then performed using the video frames and decoding header information.

This technique doesnot have ability to extract data by their own rather they take help from additional tools such as WinHex and Encase. Such tools have their own limitations like the playable video could not be produced [26].

This technique is applied to MP4 and H.264 video coding structures, and also dual common video coding standards, which are widely used in CCTVs, automobile black boxes, and mobile devices. For restoration of a specific corrupted video file, the proposed technique integrates into two phases: the connection and extraction phases. In fetching the data, stage data is extracted from an unallocated space using different forensic tools, such as WinHex and Encase. And from the taken out unallocated space, frames are extracted based on MPEG 4 and H.264.

These extracted frames are then verified using a decoder. The decoder then determines the size of the frame. However, in the phase of connection, specific frames are search over by the decoder that forms frame sets. Nevertheless, for connecting purposes, the frame's size is returned from the decoder along with the information from STSZ box which may be present in the header of the file system is also used. Though, the conventional file created video restoration methods actually illustrating some weakness to help to recover any video files, which may contain overwritten video parts, since all the video data is regularly essential to be retrieved to play the video data in just one application. In cases like severely fragmented, corrupted or overwritten video content this technique is less efficient[27]. Figure 2.2 shows that processing steps of the proposed frame-based video file restoration technique.

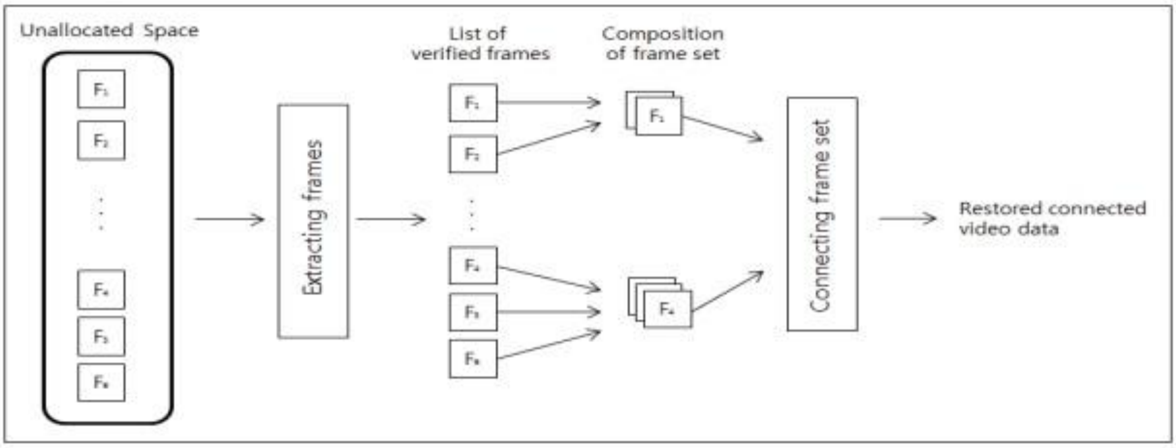

Figure 2.2: Restoration techniqueframe-based videos file [28]

Defraser is a digital forensic analytical tool that can be used to detect partial and full data streams in multimedia files. It is typically used to restore partial or complete data streams in video files, for example, an unallocated disk space. It is an open- source project developed by Nederlands Forensisch Instituut (NFI) [29]. It has the ability to find not just complete multimedia files, but also partial files, such as deleted video files that have been partly overwritten.The Defraser incorporates extensive video file format knowledge, enabling it to recognize incomplete files using any of its supported video file formats. It also offers specialized tools allowing playback of restored video frames. Additionally, it supports MPEG-1, MPEG-2, MPEG-4, AVI, ASF and 3GP video formats. Though, Defraser was found to be most successful at carving video files but the majority of recovered mp4 files were not viewable [30]. Moreover, the false positives generated by Defraser are quite large [31].The limitations of above existing techniques motivates the need of better, efficient, more general and improved video repairing tool that has ability of not only recovering but at the same time, can repairs automatically the corrupted videos.

2.6 Comparison of existing videocarving tools and technique

Table 2.1 shows a summary of file carvers reviewed in this study. Garfinkel proposed a technique that restores video files even if the header or footer is fragmented [32]. However, this technique fails when allocated memory to the file was already overwritten [33]. Bi-fragmented Gap Carving technique can only be used in a video file with two fragments, but it has a limitation when the gap between two file fragments is large [34].Though,smart carving is a technique proposed to restore files without considering a number of fragments in the file. Nevertheless, there is a drawback of this technique. When a part of allocated memory to the video is overwritten, the smart carving fails to retrieve that video [35]. However, a new technique known as Frame based recovery of damaged video files that uses video codec's specifications was recently proposed [36].

However, the method can only repair frames of non-overwritten video files and partial overwritten video files. Moreover, this technique cannot recover over-written videos completely. To date, although carving video files has been discussed by many researchers, yet there is still a big challenge for carving corrupted MP4 that have not been addressed.

Table 2.1: Comparison of file carver tool and techniques

Tool	Technique	MP4 carving	Corrupted MP4 repair to playable video	MP4 Frame carving
Scalpel		√	x	x
PhotoRec		√	x	x
	Bi-Gap Carving (BGC)	√	x	x
	Frame –based on recovery	x	x	√

MP4-Karver		√	√	x

For this research, experiments are carried out between MP4-Karver, Scalpel and PhotoRec because both are widely used open source for carving [37] [38] [39]. Secondly, both tools are also capable of doing video carving. Frame-based recovery of corrupted video files is not used in the experiment because, it only carve MP4 frame not playable MP4 video [40].

2.7 Magic numbers

As noted by digital forensics, these methods typically analyze hard drives for their contents. The entire task is to search for the kinds of files on a system. For instance, some recovery software might search for graphic files with every file extensions, such as GIF, JPG and also PNG files. However, can also be removed and their file extensions can be different, so it needs to find a method to find some types of file. Nonetheless, as a result, this would typically involve massive scans on the disk, searching for some key byte series to assistance detecting the start of a file, which is also recognized as the "magic numbers" of a file.

The starting bits of a file are what exclusively detected the types of file which sorts programming much clear as complicated files arrangements are not searched for to detect the kind of file [41]. Table 2.2below shows an example of file extensions and their file magic numbers.

Table 2.2: Magic numbers of various file types

File type	Extension	Magic Number
JPEG graphic file	.jpg	FFD8
GIF graphic file	.gif	47 49 46 38 [GIF89]
PNG graphic file	.png	89 50 4E 47 .PNG
MIDI file	.mid	4D 54 68 64 [MThd]
Icon file	.ico	00 00 01 00
AVI video file	.avi	52 49 46 46 [RIFF]
Flash Shockwave	.swf	46 57 53 [FWS]
Flash Video	.flv	46 4C 56 [FLV]
Mpeg 4 video file	.MP4	00 00 00 18 66 74 79 70 6D70 34 32 [….ftypMP42]

RAR file	.rar	52 61 72 21 1A 07 00 [Rar!]
PDF Document	.pdf	25 50 44 46 [%PDF]
Word Document	.doc	D0 CF 11 E0 A1 B1 1A E1

2.8 MPEG-4 Overview

The MPEG-4 standard has undergone some involvements since its introduction in 1999. MPEG-4 Part 1, 2, and 3 were the initial standards that outlined the file format to contain audio and video data. Moreover, the standards were defined in ISO/IEC 14496-1, ISO/IEC 14496- and ISO/IEC 14496-3 [42]. Their structure is based on the Apple QuickTime container format and was first published in 2001 by Apple, Inc. [43]. Additionally, a significant amendment to this standard was made in 2003 when MPEG-4 Part 14 was introduced and defined in ISO/IEC 14496-14 [44]. The MPEG-4 Part 14 defined the MP4 file format as it is used today and there have been many further amendments to the MPEG-4 file structure but its base has remained the same. MPEG-4 Part 10 defined in ISO/IEC 14496-10 introduced H.264/Advanced Video Coding (AVC) in 2003 [45].

Furthermore, the storage format for this encoded data was created in MPEG-4 Part 15, defined in ISO/IEC 14496-15 and released in 2004. The H.264 is the video compression standard of the BluRay Disc format. It has also been adopted for an online streaming video for services, such as YouTube, Vimeo, and Apple’s iTunes Store. On top of that, it is used for HDTV over-the-air transmissions, cable, satellite television transmissions, and is the dominant codec used by DVR’s security system and digital CCTV systems. Five MPEG-4 Part 12 described in ISO/IEC 14492-12 defined the ISO base media file format that is at the root of the analysis [46].

The definition provides the structure for a container file format to store video files locally or transmit them across a network. However, the structure and the contents of these containers are extensible and all registered extensions of the ISO base media file format are maintained by an official registration authority [47].

2.8.1 MPEG-4 file structure

The MPEG-4 file is also made of a few separated units, which is called Atoms. In the first release of the specification it was called Atom, and then now they are also known as boxes. MPEG has three main types of boxes, namely file type (“ftyp”) box - At very beginning of the file that provides information about the contents of the file.The Movie (“moov”) box - contains information about the media within the file -

e.g. its dimensions. The Movie Data (“mdat”) box - contains the raw data for video and/or audio within the file. For MPEG-4 boxes, byte size values are described in hexadecimal values using the prefix ‘0x’, where 0x00=0 bytes, 0x10=16 bytes, 0x20=32 bytes, etc [48]. Figure 2.3 shows the three main structures of MP4 video files in hex-viewer while next section explains its details.

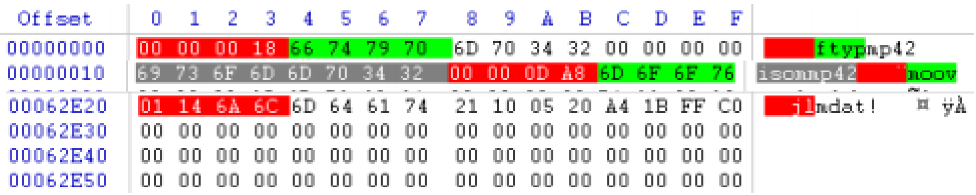

Figure 2.3 : MP4 video structure in hexviewer

Figure 2.4 shows the file type box (Ftyp), the red highlight is the first four bytes represent size of the box and equal 0x18 bytes. This measurement includes the bytes used to represent the size of the box itself. Next green highlight is the four bytes represent the type of the box and equal to 0x 66, 0x74, 0x79, and 0x70.

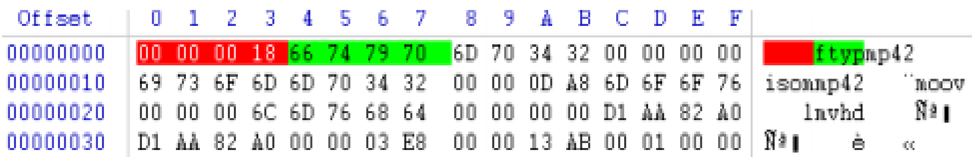

Figure 2.4: Byte 1-8 of Ftyp structure in hexviewer

Figure 2.5 shows thatthe Movie box (“moov”), the first four bytes in red represent the size of the box, which is equal to 0x0D 0xA8 bytes, there isn’t any immediate content in this box, instead there is a four-byte string identifying the size in another box. The next four bytes of green highlight represent the type of box which is equal to 0x6D, 0x6F, 0x6F, 0x76.

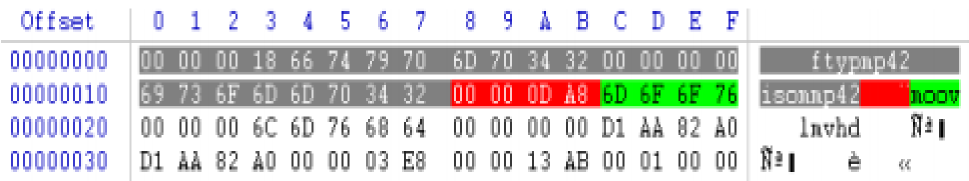

Figure 2.5: Byte 25-32 of moov structure in hexviewer

Figure 2.6 shows the Media Data Box (mdat), which contains media data of the file, in this case the compressed audio and video streams. A file may have multiple ‘mdat’ boxes containing multiple data streams or no ‘mdat’ box whatsoever if the file in question is acting only as a pointer to media data in other files. The first four bytes in red highlight represent the size of the box which is equal to 0x1, 0x14, 0x6A and 0x6C bytes. The next four bytes of green highlight represent the type of file box and is equal 0x6D, 0x64, 0x61 and 0x74.

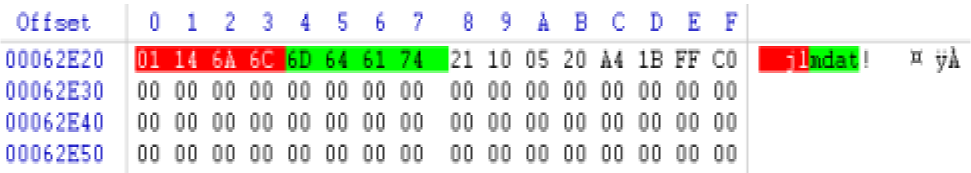

Figure 2.6 : Byte 1-8 of mdat structure in hexviewer

2.8.2 MPEG-4 codec and container

A codec can also be named as “Coder-decoder”. It provides a method of encoding audio or video into a complete stream of bytes. Familiar support encodes the video and it mainly identifies the quality of the video. Moreover, the internal section of every video file container is the audio and video data. The video data is shaped by part of an application called a codec, which is the short form of compressor and de-compressor or even compresses or decompresses the video format. However, it may be thought for the codecs that a smaller assistant of the software uses to create or play the video. If lacking of a suitable codec, a video file cannot be used on a computer [49].

The container may describe the building of a video file and where the countless sections of a container are kept in the video itself. Though, the videos may be obtained as a container, in which codecs are used in the video and by which parts of the video as well. It may also classify an audio codec in the video. It is also used to actually set the video and parts of its audio and metadata, which is all known typically by a file extension like AVI, MP4 or .MOV. All video files are basically arranged for pushing up this kind of information. In this case, each PC file has one extra layer of data in the file. Videos are usually within, and they all need to be kept in one of the simple container forms. Aside from that, inside a specific container, types like Quicktime or AVI, here could be a significant change among the video signal features, the codecs that are actually used, and also compression of the videos [50].

2.8.3 Importance of MPEG-4 video

MP4 is a video format. It may be referred to as MPEG-4 Part 14 or MPEG-4 AVC. MPEG stands for Motion Pictures Expert Group and AVC refers to Advanced Video Coding. The MP4 is a multimedia container format that permits storing of audio, video, subtitles and still images in a single file. Additionally, it also contains more complex contents, such as user interactivity, 2D, 3D graphics, animation and menus.

The MP4 works similarly to MP3. Both of them attempts to compress files and attain high quality output files. MP3 is a revolution in music and audio world. Seemingly, the MP4 technology has revolutionized in the way people's usage and share videos. The importance of MP4 video can be summarized as the following. Firstly, the MP4 may overcome MP3. The future only supports audio information, but MP4 supports video, audio and other multimedia information additionally. Secondly, it compresses multimedia information in such a way that it retains high quality in a remarkable slight file size.

Thirdly, it is a good format for sending files through the web, with aremarkable speed and outstanding quality. Fourthly, it is getting more popular as in iTunes, iPods and Play Station Potable that supports the MP4 format. It derives its importance from the popularity of portable devices. And lastly, it is greatly useful to convert each DVD into MP4 to appreciate your movies anywhere on your portable device [51].

2.8.4 Comparison of MPEG-1, 2 and 4

Table 2.3 gives comparison of MPEG-1, 2, and 4 on their features and parameters.

Table 2.3: Comparison of MPEG-1, 2, and 4 [52]

Features	Parameters	MPEG-1	MPEG-2	MPEG-4
1.Video structure	Sequence type2	Progressive	Interlace, progressive	Interlace, progressive
	Picture structure	Frame	Top/bot. field, frame	Top/bot. field, frame
2.Core compression	Picture types	I-, P-, B-pictures	I-, P-, B-pictures	I-, P-, B-rect./arb. 43video object plane (vops)

Table 2.3: continue

	Motion compression of block size	16 × 16	16 × 16 (16 × 8 field)	16 × 16, 8 × 8
3. Interlace compression	Frame and field pictures	Frame picture	Frame, field picture	Frame, field picture
	Motion compression of frame/field	No	No	Yes
	Coding frame/field2	No	No	Yes
4. Scalable video	SNR scalability	No	Picture	(Via spatial)
	Spatial scalability	No	Picture	Picture, video object plane (vop)
	Temporal scalability	No	Picture	Picture, video object plane (vop)

2.9 Performance Measurement

Equation (1) shows the percentage improvement of the MP4-Karver tool over existing tools of Photerec and Blade forensic. The percentage improvement is calculated as follows:

$$P_{im}MK(E) = \frac{PVCM - PVCE}{|Videos\ \ in\ a\ Data\ Set|} * 100 \qquad (2.1)$$

Where $P_{im}MK$ is the percentage (**P**) improvement ($\boldsymbol{im}$) of MP4-Karver (MK)over existing (**E**) tool. P*VCE* is the **v**ideo **c**arved by **e**xisting tools and P*VCM is* the **v**ideo **c**arved by MP4-Karvertool. The values obtained from VCE-VCM are divided by the total number of videos in a data set. To get the percentage 100 is multiplied. In next step the average of percentage improvement of MP4-Karver over existing tools is calculated by using the equation (2):

$$AP_{im}MK(E) = \frac{\sum_{i-0}^{|Data\ \ sets\,|} P_{im}MK(E)_i}{|Data\ \ Sets\,|} (2.2)$$

The Equation (2) sums up all the values of Equation (1) obtained for all the data sets and divided it by the total number of the data sets.

2.10 Chapter Summary

This chapter discusses file carving, especially on MP4 video carving tools, its techniques, and comparison of these tools, MP4 overview and performance measurement. The beginning of this chapter gives a summary of existing tools and techniques in video file carving. As mentioned, earlier conventional techniques for video file restoration uses meta-data on file system to retrieve a video file stored in a storage medium, such as a hard drive or a memory card. The file system's meta-data contains information, such as address and the link to a video file that can be used for file restoration, for instance, the Sleuth Kit tool. Video file restoration may not be possible with such techniques when the file system meta-information is not available.

Through that signature-based video, restoration technique was proposed to address this problem. This method creates a database of the file header (beginning mark of the file) and footer (the end mark of the file) and defines a set of rules for a specific file type.

The Signature-based file recovery techniques do not require file system information. Scalpels, Formost, are the tools and techniques based on file header and footer signature carving. They do have drawbacks when the file header and footer do not exist. On the other hand, Bi Gap Carving technique was proposed and the method can only be applied to a video file with two fragments and this technique has a limitation when the gap between the two file fragments is large.

Smart carving technique was proposed to restore a file without being restricted by the number of fragments. This technique identifies the occurrence of fragmentation, combines permutations of fragmented components and searches for fragment order. However, the method is also a file-based approach, having a limitation to restore a video file when a part of video file was overwritten. An overview of file carving is explained in Section 2.2 which gives definitions of file carving, the powerful file carving technique to restore files. It also explains the usefulness of file carving, especially in criminal cases where it could recover evidences.

As presented in Section 2.3, video carving highlights the usage of video files, popularity and the capability of restoring and analyzing video data crucial for forensic examiners. Section 2.4 explains the existing file carving tools of Defraser, PhotoRe, EnCase, ILook, Scalpel, R-Studio and techniques of Smart Carving, Bi fragmented Gap Carving, Frame based on Recovery are highlighted. Section 2.5 gives comparison of existing file carving tools of Scalpel, Garfinkel, Smart Carving, Bi-fragmented Gap Carving, Frame based on Recovery. Section 2.6 presents Magic Number that is used for file carving searching for some key byte series to detect the start of a file, which is also recognized as the “magic numbers”. Section 2.7 highlights MP4 overview of MP4 video and the parts of MP4 video contents. It also discusses details of MP4 video structure, video container and codec, the importance of MP4 video and comparisons between MPEG-1, 2 and 4. It lastly explains adapted performance measurement equation for calculating the percentage improvement of the tools.Next chapter discusses the methodology of the proposed MP4-Karvel tool.

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